

The Issue of Coexistence over Power Line Wires

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An Old Joke

***“The nice thing about standards is that
there are so many to choose from!”***

Unfortunately, this does not apply to PLCs yet!!!

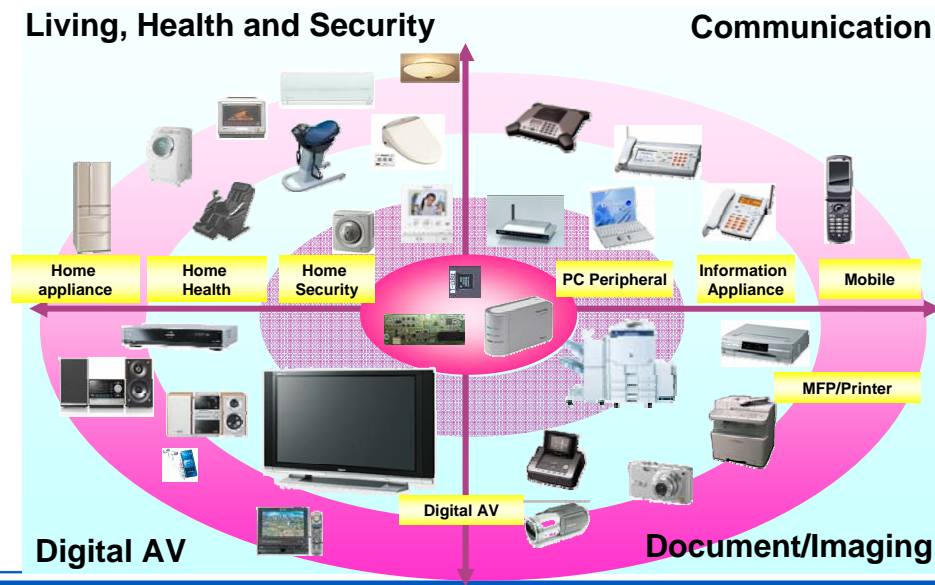
But maybe it will apply next year....

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The Next Challenge: Connect Everything



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The HD-PLC Alliance

■ HD-PLC Alliance (HDPLCA)

■ Established Sep. 2007

■ Objective

- Popularize HD-PLC technology
- Ensure inter-operability among products adopting HD-PLC
- Promote industry standards

■ Organization

- Promoted by Panasonic Corporation
- Non for profit organization

■ Homepage: www.HD-PLC.org

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The HD-PLC Alliance: Ecosystem of Products



Panasonic and Smart Grid/Access

- Panasonic business goes beyond entertainment and includes appliances, photovoltaic, batteries, energy efficiency management systems and networking equipment.
- Panasonic is the only Fortune 500 Company that designs, manufactures, embeds, and sells PLC technology
 - Wavelet HD-PLC technology incorporated in IEEE 1901 standard
 - Worldwide tests confirm its effectiveness in Smart Grid (MDU applications, monitoring systems for prisons, ski resorts, street, etc, field trials on LV for triple play applications, PLC as return channel for Digital TV (Samba Project), Anti-tampering AMR technology)
- Smart Grid success will depend on consumer adoption in the home, thus harmonization of Smart Grid applications with in-home broadband applications is necessary

The Problem of Self-Interference

- Power lines are a shared medium: signals generated by one user in one apartment or house interfere with the signals generated in an adjacent house or apartment
- Since it is difficult to contain locally the signals generated by a user, the more PL modems in geographical proximity the more interference
- This phenomenon is not dissimilar from what happens in other more conventional shared media, e.g., coax and wireless
 - However, coax and wireless devices can count on the availability of a much larger bandwidth than in the PL case and can therefore mitigate the effects of interference by using different communication channels
- Today no products have tools to solve this problem

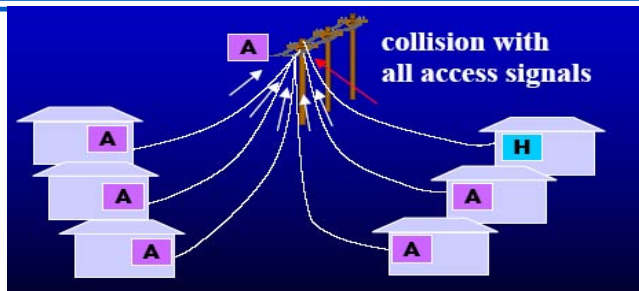
In-home and utility power line networks will collide!
In-home power line networks will collide with each other!

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The Biggest Challenge: Coexistence



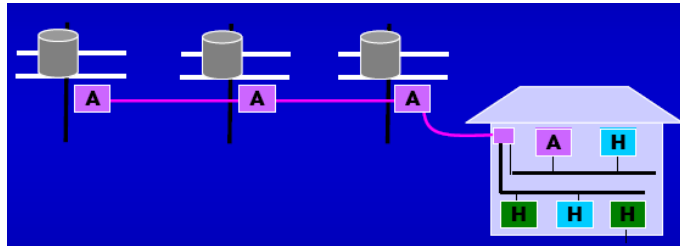
- Power line cables are a shared medium, like coax cable and unlike DSL. Similarly to cable, mass deployment causes backbone capacity issues to arise
- Signals in your home are interference for your neighbor, and viceversa, regardless of whether you are subscribed to access or not
- Not only complicated MAC problem, also security issues... but not that different from wireless 802.11

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The Biggest Challenge: Coexistence



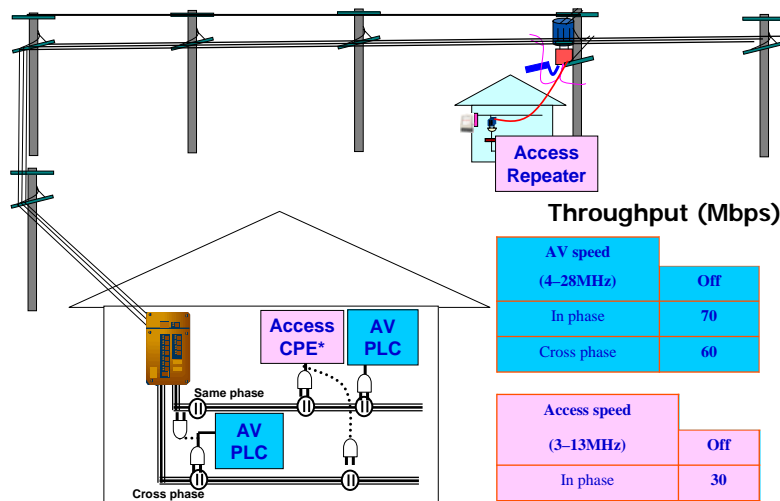
- There is no demarcation between access and in-home power line cables → it is a bus running from sub-station transformer to every plug in the home
- Access signals and in-home signals must co-exist

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The Biggest Challenge: Coexistence



Throughput (Mbps)

AV speed (4-28MHz)	Off
In phase	70
Cross phase	60

Access speed (3-13MHz)	Off
In phase	30
Cross phase	30

*CPE = Customer Premise Equipment

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A Solution for Efficient Resource Sharing: Co-Existence

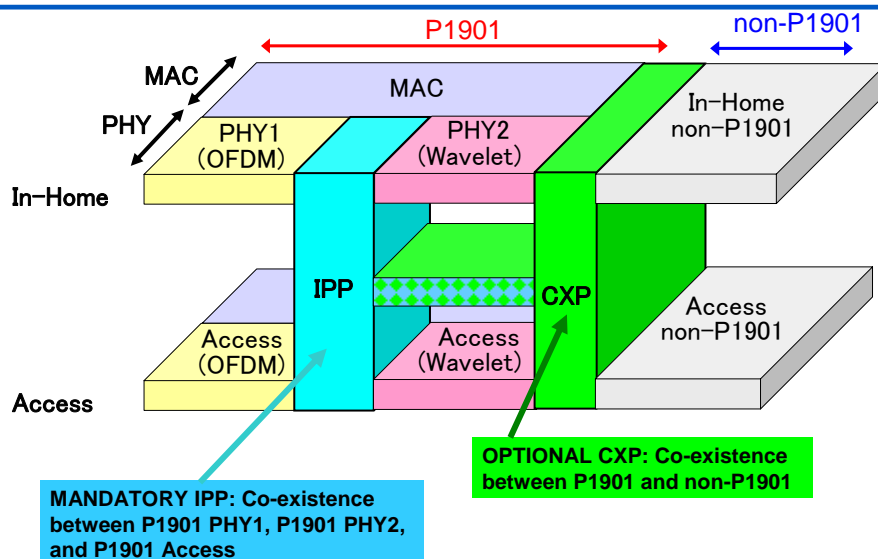
- The Inter PHY protocol (IPP) is a simple resource sharing mechanism dedicated to IEEE P1901 devices which have the P1901 MAC and either the Wavelet OFDM or the Windowed FFT OFDM P1901 PHY
 - Also being standardized in ITU: consented G.992 Recommendation
- IPP originally conceived to handle the dual PHY in P1901, but it has been extended to ensure co-existence in the following cases (ISP):
 - Co-Existence between in-home and access/smart grid
 - Coexistence between IEEE 1901 and ITU G.hn
 - Allows In-Home and Access technology to progress with different obsolescence horizons

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IEEE P1901 Baseline Document: Co-Existence

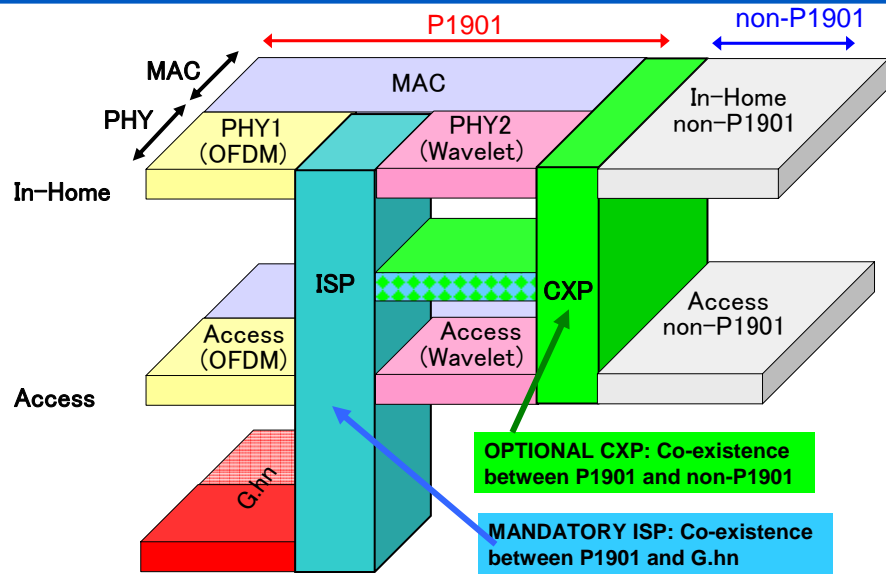


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IEEE P1901 Baseline Document: Co-Existence



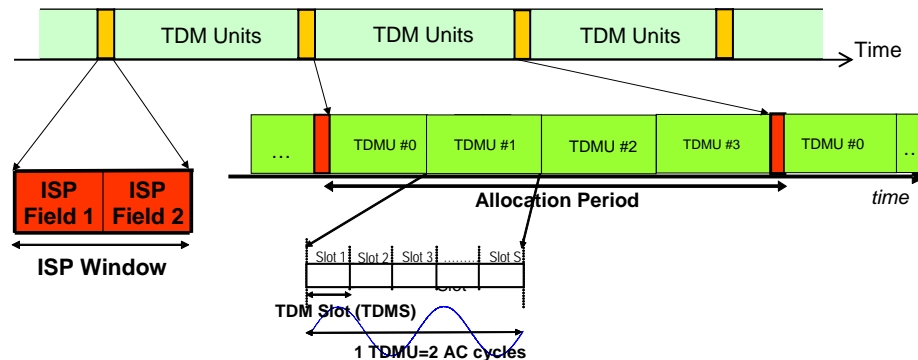
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IEEE P1901 and G.cx: Inter-System Protocol (ISP)

- Co-existence protocol simpler than full CXP
- Dynamic allocation, with centralized and distributed features
- Time-reuse algorithm for increasing network throughput



For more details: Galli, Kurobe, Ohura, "The Inter-PHY Protocol (IPP): A Simple Co-Existence Protocol," IEEE Int. Symp. on Power Line Comms., March 2009.

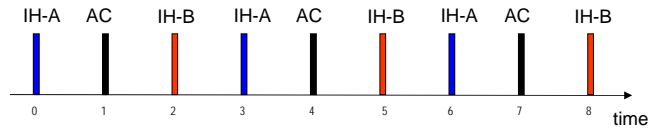
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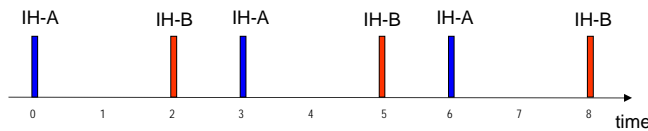
Network Status

Each system transmits special signals with appropriate timing and order



Three systems present:

- IH with PHY-A
- IH with PHY-B
- AC present



Two systems present:

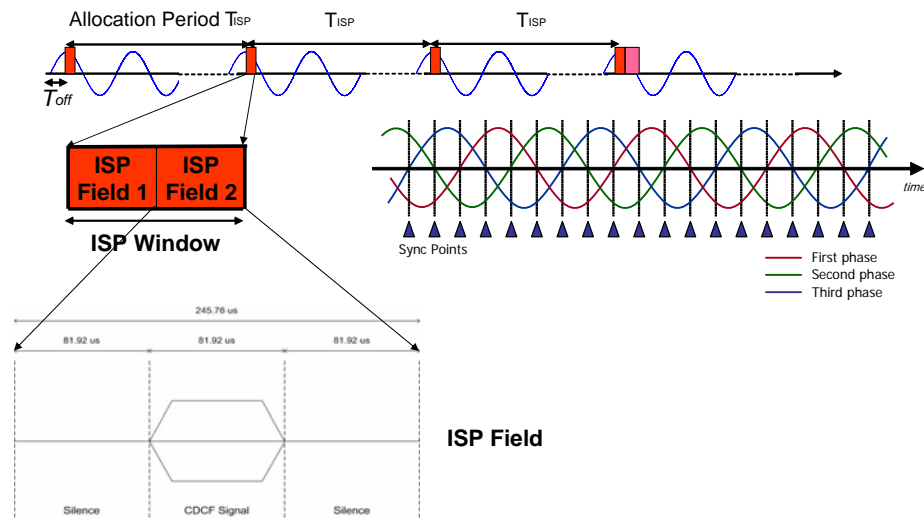
- IH with PHY-A
- IH with PHY-B
- No AC present

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ISP Window and ISP Fields



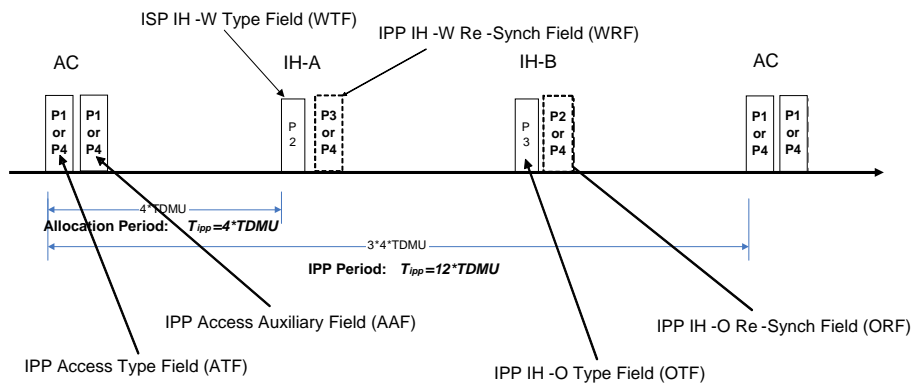
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ISP Waveform and Network Status

- ISP signal will be:
 - Transmitted periodically in round robin at a fixed offset from zero crossing
 - Transmitted simultaneously by all nodes (not only the masters) that are in same system type (AC, IH-A or IH-B)
 - Detected by all nodes in every period



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Fundamental Concepts in ISP

- TDMU allocations determined by network status
 - Detection of ISP signals over any period of $3 \cdot T_H$ univocally determines the network status
 - The function that associates network status to TDMU allocations must be surjective and monodromous
 - TDMU allocations are changed when a change in network status is detected, thus allowing Dynamic Bandwidth Allocation (DBA)
- Nodes make local decisions
 - Network status is a "per node" concept
 - There may be multiple TDMU allocations usable by nodes even within the same system
 - Nodes must agree on common allocations for communicating

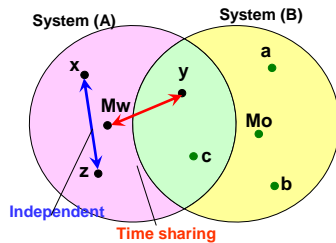
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Time Slot Re-Use

- In order to share resource efficiently among systems with different PHY, there has to be a mechanism that allows devices to use the same time slots simultaneously (STR)



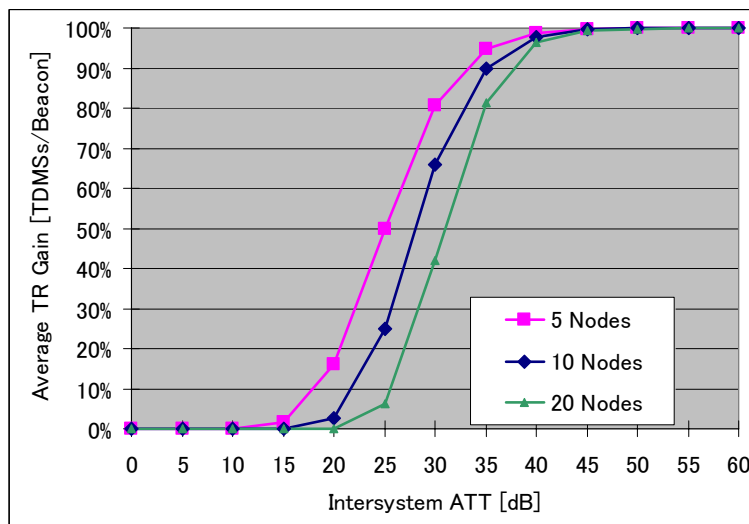
Concept

- Every node in a system transmits ISP at the same time
- Each node in a system detects the superposition of all the ISPs transmitted by the nodes in another system, and detects the network status
- Nodes make local decisions whether they have to share resources or not

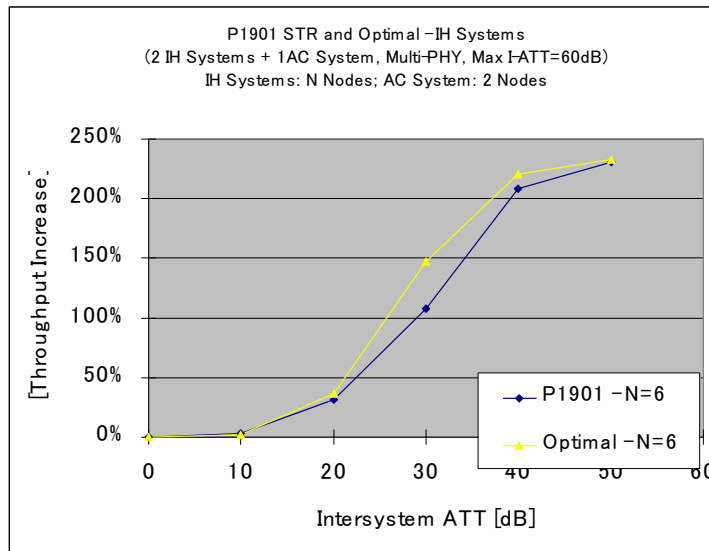
Nodes x and z in system (A) do not detect ISP from system B → no sharing

Node y in system (A) detects ISP from system (B) → sharing needed

Time Slot Re-Use: 2 IH Systems



Time Slot Re-Use: 3 Systems, 2 IH and 1 AC



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Conclusive Remarks

- Fundamental issue for success of PLC technology is coexistence:
 - o Coexistence is the ability for different PLC systems to function simultaneously at acceptable levels of performance
- The Inter System protocol (ISP) is a simple and flexible co-existence mechanism being developed in IEEE and ITU-T
- Originally conceived to handle the dual PHY in P1901, but it has been extended to ensure the following important features
 - o Allows co-existence between in-home and access/smart grid
 - o Coexistence between IEEE 1901 and ITU G.hn
 - o Allows In-Home and Access technology to progress with different obsolescence horizons
- The ISP allows achieving fine synchronization among neighboring networks and time-reuse gains to alleviate self-interference issues

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Recommendations to NIST

RECOMMENDATIONS:

Panasonic makes the following recommendations to NIST for inclusion in its Interoperability Framework:

- Include ITU-T G.9972 in the approved list of Smart Grid standards.
- Include a recommendation that all Smart Grid PLC standards utilize the ITU-T G.9972 coexistence standard or successor standards.
- Include IEEE 1901 in the approved list of Smart Grid standards. Note that since the ISP coexistence protocol defined in the IEEE 1901 Draft mirrors exactly Recommendation G.9972, then the IEEE 1901 Standard would satisfy the recommendation in the second bullet.
- Include in its list of recommended communications PHY/MAC standards only those PLC technologies that have been developed by a “voluntary consensus standards body” as defined by OMB Circular A-119.¹¹